

**CRYSTALLIZATION OF YAMATO 980459 AT 0.5 GPa: ARE RESIDUAL LIQUIDS LIKE QUE 94201?**

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**Introduction:** The Martian basaltic meteorites Y980459 and QUE94201 (henceforth referred to as Y98 and QUE respectively) are thought to represent magmatic liquid compositions [1-4], rather than being products of protracted crystallization and accumulation like the majority of other martian meteorites. Both meteorite compositions have been experimentally crystallized at 1 bar [2,4], and liquidus phases were found to match corresponding mineral core compositions in the meteorites, consistent with the notion that these meteorites represent bona fide melts. They also represent the most primitive and most evolved basaltic martian samples, respectively. Y98 has Mg# (molar Mg/Mg+Fe) ~ 65 [4], and lacks plagioclase; whereas QUE has Mg# ~ 40 [5], and lacks olivine. However they share important geochemical characteristics (e.g. superchondritic CaO/Al<sub>2</sub>O<sub>3</sub>, very high  $\epsilon_{Nd}$  and low <sup>87</sup>Sr/<sup>86</sup>Sr) that suggest they sample a similar highly depleted mantle reservoir [6, 7]. As such, they represent likely endmembers of martian magmatic liquid compositions, and it is natural to seek petrogenetic linkages between the two. We make no claim that the actual meteorites themselves share a genetic link (the respective ages rule that out); we are exploring only in general whether primitive martian liquids like Y98 could evolve to liquids resembling QUE.

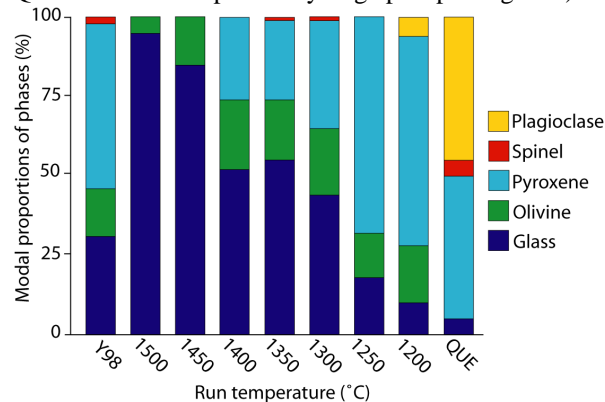
Both experimental and computational efforts have been made to determine if there is indeed such a link. Recent petrological models at 1 bar generated using MELTS [8] suggest that a QUE-like melt can be derived from a parental melt with a Y98 composition. However, experimental studies at 1 bar have been less successful at replicating this progression [9]. Previous experimental crystallization studies of Y98 by our group [10] at 0.5 GPa have produced melt compositions approaching that of QUE, although these results were complicated by the presence of small, variable amounts of H<sub>2</sub>O in some of the runs owing to the use of talc/pyrex experimental assemblies. Therefore we have repeated the four experiments reported by [10], augmented with additional runs, all using BaCO<sub>3</sub> cell assemblies, which are devoid of water, and these new experiments supersede those reported earlier. Here we report results of experiments simulating equilibrium crystallization; fractional crystallization experiments are currently underway.

**Experimental and Analytical :** Starting material was Y98A glass powder conditioned at the iron-wüstite buffer at 1000°C for ~24 hours. This material is the same as used in a variety of studies [3,4,9,10], thus eliminating at least one source of discrepancy between them. Experiments were carried out in BaCO<sub>3</sub> cells fitted with graphite heaters and sample capsules in a Depths of the Earth 13mm piston-cylinder apparatus at NASA Johnson Space Center. BaCO<sub>3</sub> was used in order to ensure anhydrous conditions, reducing the variability observed previously due to incorporation of H<sub>2</sub>O from talc-pyrex assemblies. Experiments were heated to 1600°C, well above the Y98 liquidus at 0.5 GPa, and held for 15 mins before dropping to the target temperature over 2 – 3 mins where they were held for several hours before quenching by cutting power to the assembly. The successful run products were sectioned, mounted in epoxy and analyzed at 15kV and 20 nA using the Cameca SX100 electron microprobe at NASA Johnson Space Center. Phase compositions were used to calculate modal abundances of all phases via least-squares mass balance.

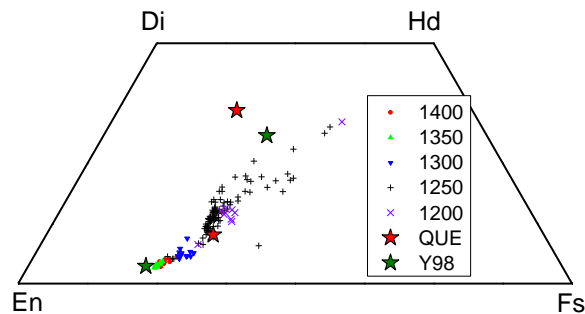
**Results:** The experiments reported here were conducted at 1500°C – 1200°C at 50°C intervals. All experimental assemblages contain olivine ranging in composition from Fo<sub>80</sub> (highest T) to Fo<sub>68</sub> (lowest T). Pyroxene begins crystallizing at 1400°C (figure 1), and evolves compositionally from very close to the pyroxenes in Y98 towards the pyroxene core compositions in QUE, although they do not exactly match. The experimental pyroxenes trend towards a more Fe-rich composition than found by [12], however there is more recent evidence of more Fe-rich pyroxene in QUE [5]. Chromite crystallizes in small amounts at 1350 - 1300°C, but is absent in lower temperature runs. Plagioclase does not appear until the lowest temperature run (1200°C), and in much smaller proportions than is present in QUE. Olivine also crystallizes in this lowest T run, whereas it is not present in QUE.

Although the mineral phases of the experimental charges do not match exactly with QUE, residual liquids evolve to major element compositions very similar to that of QUE (figure 3) except for P<sub>2</sub>O<sub>5</sub> and TiO<sub>2</sub>. However, these differences may be quite easily explained from the small sample size of QUE (merely 7 grams); its grain size is somewhat coarse compared to the overall size of the specimen such that obtaining a

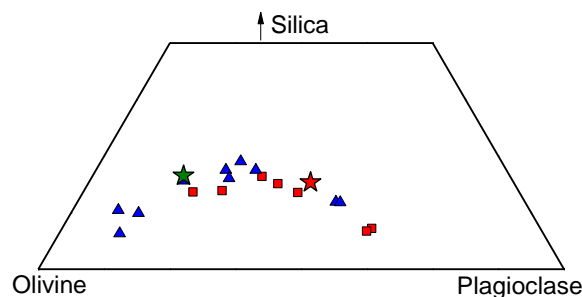
reliable bulk composition is challenging, especially for minor elements (particularly true for  $P_2O_5$  because QUE contains comparatively large phosphate grains).



**Figure 1** Modal proportions of phases in each run, compared to Y98 and QUE.



**Figure 2** Pyroxene quadrilateral, comparing experimentally produced pyroxene compositions to those of pyroxene cores in Y98 [11] and QUE [12]. See text for discussion.



**Figure 3** Olivine-silica-plagioclase pseudoternary demonstrates the relationship between the experimental liquid compositions (red squares) and calculated parental melt compositions for shergottite meteorites (Shergotty, Zagami, EETA79001 A&B, ALHA 77005, Los Angeles, LEW 88561, DAG 476, Dhofar 019 [15-20]) (blue triangles). Y98 and QUE [2, 1] are represented by green and red stars respectively.

**Discussion and Implications:** The liquid that evolves as Y98 crystallizes matches very closely with the melt composition of QUE, however the crystal compositions are not such a close match. The discre-

pancy between olivine compositions in our experiments and Y98 may be because there is a small amount of cumulus olivine in Y98, giving rise to artificially high Fo content in some olivine cores [11]. There is also some evidence that  $fO_2$  plays a role in the crystallization of martian magmas such as these. At 1 bar, under more oxidizing conditions (MH) olivine crystallizes, whereas it does not under more reduced conditions (IW-1) [2]. Similarly QUE is extremely enriched in  $P_2O_5$ , which has been shown to suppress olivine crystallization at low  $fO_2$  [12]; however as mentioned above the bulk  $P_2O_5$  content of QUE is likely uncertain. Also, the bulk composition of QUE plots in the olivine field on a qz-ol-plag pseudoternary [5], however there is no olivine present in the meteorite.

**Next steps:** The experiments reported here begin to reveal a complex relationship between martian basaltic liquids with compositions like Y980459 and QUE94201. Our experiments suggest that the two meteorites may indeed sample geochemically similar source regions, although their petrogenetic history is clearly not a simple one of crystallization at shallow depth under equilibrium conditions. Therefore the next step in attempting to understand this system, and by extension igneous processes on Mars, is to carry out the same experiments under fractional conditions. Potentially this may force the crystal compositions towards a more evolved composition, producing a result more like QUE. Another important variable to consider is the influence of  $H_2O$  on the system, as it is now well established that at least the surface of Mars was wet. The role of water must be studied in a systematic fashion to determine the extent to which it may affect phase equilibria and evolution of liquid compositions in martian magmas. These hydrous runs will mimic both equilibrium and fractional crystallization processes.

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